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Flow-Mechanically Effective Surface for Minimizing Induced Resistance

The invention relates to a flow-mechanically effective surface of a device moving in a fluid, especially a flying machine, especially a supporting or lifting surface of a flying machine, whereby the surface comprises an elastic axis extending in the span direction of the surface and an adjustable control surface, as prescribed in the preamble of the claim 1.

In connection with a device moving in a fluid, there arises during the movement through the fluid, thus perhaps in connection with a flying machine during flight, a deformation of the flow-mechanically effective surface, thus of the lifting surface of the flying machine. This deformation is variable or changeable and depends on the effective aerodynamic forces and the inertial and/or mass forces. These are dependent on the flight condition (speed, altitude), as well as on the loading condition (useful payload, fuel quantity, position of center of gravity). Without special measures, a wing can only be designed so that it comprises the deformation that is most advantageous for the aerodynamic resistance only for a single condition and time point of a flight. A different deformation, which is not resistance-minimal, arises for every other condition and for every other time point.

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In the state of the art, no systems have previously become known, with which the structural deformation of wings can be adapted or matched to a form or shape that is optimal for the aerodynamic resistance. The influence of the structural deformation was either neglected or disregarded, simply put up with, or in the best case taken into consideration such that the deformation that is most advantageous for the aerodynamic resistance arises for an "average" flight condition (average loading, half flight time).

While, of course, control surfaces that are per se adjustable are known on such flow-mechanically effective surfaces such as the lifting surface of a flying machine, these, however, serve for the control of the flight attitude or the trimming of the aircraft, but not, however, a change or variation of the deformation of the wing in the sense of an adaptation or matching to the form that is most advantageous for the aerodynamic resistance dependent on the flight and loading condition. It is also known, to use conventional control surfaces on the wing trailing edge (aileron) for influencing the aerodynamic pressure distribution for a smaller structural loading (load reduction), a similar control surface concept has also become known for improving the roll control for an experimental version of a combat aircraft, similarly also for the same purpose the additional use of flaps along the wing leading edge.

The aerodynamic pressure distribution and the structural loading change or vary due to differing flight conditions (altitude,

speed) and loading conditions (useful payload, fuel, position of center of gravity), whereby different elastic deformations arise. This deformation condition influences the aerodynamic (lift induced) resistance. For a given span, and without consideration of the structural loading, the minimal resistance arises for an elliptical aerodynamic pressure distribution over the span. This can be achieved through an elliptical wing plan form or through a corresponding torsion or twisting of the wing profile chord in the span direction relative to the direction of incident flow or relative wind. A wing torsion deformation in the span direction (twisting) as well as a bending deformation on the swept-back wing influence this distribution. Therefore, the resistance-minimal deformation condition can only prevail for a short time during the total duration of a flight, in which the fuel quantity changes and the flying proceeds with different speeds at different altitudes. Moreover, the magnitude of the deformation is dependent on the loading condition.

The object of the invention is to present a flow-mechanically effective surface of a device moving in a fluid, especially a flying machine, especially a lifting surface of a flying machine, which comprises a deformation that is most advantageous for a minimal flow-mechanical resistance, to the extent possible for every condition.

This object is achieved by the flow-mechanically effective surface set forth in the claim 1.

Advantageous further developments of the subject of the invention are presented in the dependent claims.

Through the invention there is provided a flow-mechanically effective surface of a device moving in a fluid, especially a flying machine, especially a lifting surface of a flying machine. The surface comprises an elastic axis extending in the span direction of the surface, and an adjustable control surface. According to the invention it is provided that the surface is elastically deformable in the bending direction and/or in the direction about the elastic axis, dependent on the adjustment of the control surface, in connection with change of the induced flow-mechanical resistance, and that a control and/or regulating device for adjusting the control surface in the sense of a minimization of the induced flow-mechanical resistance of the surface is provided. A significant advantage of the inventive flow-mechanical surface is that a distribution of the lift force over the wing span, which distribution is optimal for the resistance, can be produced for practically every flight and loading condition. For the lifting surface of an aircraft this means that an adaptation of the deformation can be achieved for practically every flight condition through the invention. Moreover, the invention can be used to advantage for additional functions, such as the support or assistance of the roll control, a load reduction, an improvement of the flutter stability, and a use for the stabilization and/or control of the lateral movement about the aircraft vertical axis, in case the plane of the control surface comprises a vertical component.

Preferably, the control surface is arranged offset by a prescribed spacing distance relative to the elastic axis.

Preferably the control surface is arranged supported rotatably about a rotation axis, and the rotation axis or at least a component thereof extends in the direction of the elastic axis.

According to an embodiment of the invention, the control surface can be arranged by a prescribed spacing distance behind the elastic axis.

According to a preferred embodiment of the invention, the control surface is arranged by a prescribed spacing distance in front of the elastic axis. The mounting of the control surface in front of the elastic axis means that the wing deformation supports or assists the desired aerodynamic force effect, while the aerodynamic force from the deformation acts contrary to the desired direction in connection with a position of the control surface behind the elastic axis.

According to an embodiment of the invention, the control surface can be arranged within the wing span.

According to a different preferred embodiment of the invention, the control surface can be arranged outside of the wing span. This achieves an effective enlargement of the wing span.

According to an embodiment of the invention, the control surface can be arranged behind the leading edge of the surface.

According to a different preferred embodiment, the control surface can be arranged in front of the leading edge of the surface. This achieves an enlargement of the lever with which the control surface acts relative to the elastic axis.

According to a preferred embodiment of the invention, the control surface can be provided in addition to a wing tip surface (winglet) on the surface end or tip.

According to a different preferred embodiment of the invention, the control surface itself can be embodied as a wing tip surface (winglet).

In this regard it is advantageously provided that the rotation axis of the control surface forming the wing tip surface extends slopingly or obliquely relative to the direction of the elastic axis.

In the two just-mentioned embodiments, the surface is advantageously especially a lifting wing of a flying machine, whereby the wing tip surface (winglet) continues the lifting wing at its end, sloping obliquely or extending vertically upwardly.

In this regard, the surface is especially a lifting wing of a flying machine, whereby the wing tip surface (winglet) continues

the lifting wing, sloping obliquely or extending vertically upwardly, and the control surface continues the lifting wing in its direction or continues the lifting wing sloping obliquely downwardly. In combination with the winglet, the control surface results in a second wing tip, whereby two edge or tip vortices are formed, which similarly contributes to the reduction of the induced resistance.

According to preferred embodiments and applications of the invention, the surface is the lifting surface of an aircraft.

Alternatively, the surface can be the lifting surface of a rotary wing aircraft.

According to an advantageous embodiment of the invention, a control arrangement is provided, which produces an adjusting or actuating signal for the control surface from data relating to the aircraft loading and the flight condition, while using stored desired or nominal value data or comparison data.

According to a different advantageous embodiment of the invention, a regulating arrangement is provided, which produces an adjusting or actuating signal for the control surface by comparison of measured data, for example data measured in an optical manner, representing the actual elastic deformation of the flow-mechanically effective surface, with desired or nominal data representing a nominal or desired deformation of the

flow-mechanically effective surface prescribed for the aircraft loading and the flight condition.

In the following, example embodiments of the invention will be explained in connection with the drawings. It is shown by:

Fig. 1 a schematic perspective illustration of a lifting surface of an aircraft according to a first example embodiment of the invention;

Fig. 2 a schematic perspective illustration of a lifting surface of an aircraft according to a second example embodiment of the invention;

Fig. 3 a schematic perspective illustration of a lifting surface of an aircraft according to a third example embodiment of the invention;

Fig. 4 a schematic perspective illustration of a lifting surface of an aircraft according to a fourth example embodiment of the invention;

Fig. 5 a schematic perspective illustration of a lifting surface of an aircraft according to a fifth example embodiment of the invention;

Fig. 6 a schematic perspective illustration of a lifting surface of an aircraft according to a sixth example embodiment of the invention;

Fig. 7 a diagram, which represents the relationship between lift distribution and induced resistance for the case of conventional lifting surfaces and for the case of a lifting surface according to example embodiments of the invention;

Fig. 8 a diagram, which shows an example embodiment for the control of the deformation of a lifting surface of an aircraft according to example embodiments of the invention; and

Fig. 9 a diagram, which shows an example embodiment for the regulation of the deformation of the lifting surface of an aircraft according to example embodiments of the invention.

Six different example embodiments of flow-mechanically effective surfaces, namely of lifting surfaces of an aircraft, are illustrated in the Figs. 1 to 6. The surface 1 is respectively illustrated in a schematic perspective manner, and the direction of incident flow or relative wind during flight is indicated by a correspondingly designated arrow. The surface 1 has a span direction 6, which increases with the illustrated arrow beginning from the fuselage of the aircraft, which is not expressly

illustrated. An elastic axis EA, about which the surface 1 is deformable in the torsional direction and in the bending direction, extends in the span direction 6 of the surface 1.

An adjustable control surface 3, which is respectively differentiated with 3a, 3b, 3c, 3d, 3e, 3f in the various example embodiments, is respectively provided on the surface 1.

For all of the example embodiments illustrated in the Figs. 1 to 6, it applies that the surface 1 is elastically deformable in the bending direction and/or in the direction about the elastic axis EA, that is to say in the torsion direction, due to the aerodynamic forces effective during flight, dependent on the adjustment or setting of the control surface 3 while varying or changing the induced flow-mechanical resistance. This elastic deformation is adjusted or set by a control and/or regulating arrangement such that the induced flow-mechanical resistance of the surface 1 is minimized. The control and/or regulating arrangement will later still be explained in more detail.

The control surface 3 is arranged offset by a prescribed spacing distance relative to the elastic axis EA, as it is the case with the control surfaces 3a, 3b, 3c, 3d, 3e of the Figs. 1 to 5, or it is at least arranged such that a readjustment of the control surface will lead to a change of the deformation of the surface 1 in the bending direction and/or in the direction about the elastic axis EA, as shown for the control surface 3f of the example embodiment of Fig. 6. (The elastic axis EA is

illustrated only in the example embodiment of Fig. 1 for the sake of simplicity, it is, however, present in a similar manner in the remaining example embodiments).

In the example embodiments of the Figs. 1 to 4, the control surface 3a, 3b, 3c, 3d is arranged rotatably supported about a rotation axis 4, whereby the rotation axis 4 extends essentially in the direction of the elastic axis EA; in the example embodiments of Fig. 5 and Fig. 6 the control surface 3e, 3f is arranged rotatably supported about a rotation axis 4 whereby a component of the rotation axis 4, namely the projection thereof onto the direction of the elastic axis EA, extends in the direction of the latter.

In the example embodiments of the Figs. 1 to 5, the control surface 3a, 3b, 3c, 3d, 3e is arranged by a prescribed spacing distance in front of the elastic axis EA (relative to the direction of incident flow). As is easily understandable, this leads to the result that a deformation of the lifting surface 1 in the torsion direction about the elastic axis EA due to a re-adjustment of the control surface 3a, 3b, 3c, 3d, 3e involves an increase or amplification of the effect of the latter, so that the adjustment or setting of the control surface 3a, 3b, 3c, 3d, 3e is thus effective in a progressive self-amplifying manner, thus the control surface 3 must be less strongly readjusted. In contrast thereto, in example embodiments that are not illustrated here, the control surface 3 may also be arranged by a prescribed spacing distance behind the elastic axis EA (with respect to the

direction of incident flow), which then contrarily leads to the result that a deformation of the surface 1 due to the adjustment of the control surface 3 has a weakening effect, so that the control surface 3 must be more strongly readjusted.

In the example embodiments of Fig. 2 and Fig. 4, the control surface 3b, 3d is arranged within the wing span, whereas in the example embodiments of the Figs. 1, 3, 5 and 6 it is arranged outside of the wing span, compare the control surface 3a, 3c, 3e, 3f in the above mentioned Figures. The latter manner of the arrangement thus leads to an effective enlargement of the wing span.

The control surface 3 can be arranged behind the leading edge of the surface 1, with respect to the direction of incident flow, as is the case with the control surfaces 3a, 3b of the Figs. 1 and 2, and in the broader sense also for the control surface 3f of the Fig. 6, which will later still be explained in more detail.

On the other hand, the control surface 3 can also be arranged in front of the leading edge of the surface 1, with respect to the direction of incident flow, as with the control surfaces 3c, 3d of the Figs. 3 and 4, and in the broader sense also for the control surface 3e of Fig. 5, which similarly will later still be explained.

The control surface 3 can be provided at the end or tip of the surface 1 additionally to a wing end or tip surface 2 (winglet), as is the case with the control surfaces 3a, 3b, 3c, 3e of the Figs. 1, 2, 3, and 5, or the control surface 3 can itself be embodied as a wing tip surface, as with the control surface 3f of Fig. 6. In the latter, the rotation axis 4 of the control surface 3f forming the wing tip surface 2 (seen in the vertical plane) extends obliquely relative to the direction of the elastic axis EA.

As can be seen, the wing tip surface (winglet) 2 continues the lifting wing or rather the surface 1 at its end obliquely or vertically upwardly in the example embodiments illustrated in the Figs. 1, 2, 3 and 5. In the example embodiments of the Figs. 1 to 4 the control surface 3a, 3b, 3c, 3d continues the lifting wing or rather the surface 1 in the direction thereof or lies in the same, in the example embodiment of the Fig. 5 the control surface 3e continues the lifting wing 1 obliquely downwardly.

In the example embodiment of the Fig. 6, the control surface 3f itself forms the wing tip surface and continues the same in the direction obliquely upwardly.

The diagram illustrated in Fig. 7 shows the relationship between the lift distribution and the induced resistance over the span direction y. An elliptical distribution of the lift, which corresponds to a minimal induced aerodynamic resistance, arises for an even, planar or level wing with an elliptical plan form.

With a non-elliptical plan form of the wing or rather the surface 1, a corresponding lift distribution can be achieved by different twisting or torsion of the wing profile chord relative to the direction of incident flow in the span direction. The same effect arises through different wing deformation conditions. Through the control surface 3, the elastic deformation can be adapted or matched to the minimal-resistance form. An elliptical distribution with minimal resistance ($k = 1.0$) is illustrated, and as well non-elliptical distributions ($k > 1.0$) are illustrated in a dotted and dash-dotted manner.

In a schematic illustration, Fig. 12 shows an example embodiment for the control of the deformation of the surface 1 by a readjustment of the control surface 3. Aircraft loading data and flight condition data are produced from measurements and calculations. From these aircraft loading and flight condition data, stored data in the form of tables with desired or nominal values, which are determined from calculations or from measurements, are derived (11), a command for the control of the control surface 3 in the form of an actuating or adjusting signal is derived (12) from these derived nominal value data, and with the help of this actuating signal the control surface 3 is adjusted in the sense of a minimization of the induced flow-mechanical resistance of the surface 1, as explained initially above.

Fig. 9 shows a schematic diagram for the regulation of the deformation of the surface 1 by the control surface 3. The

actual deformation of the surface 1 is measured (13), for example in an optical manner, and the measured data acquired thereby, which represent the actual deformation of the surface 1, are compared (14) with desired or nominal data of a desired or nominal deformation that is optimal in the sense of a minimization of the induced resistance for the existing flight condition and the aircraft loading, from this comparison a command for the readjusting of the control surface 3 is produced (15) in the form of an actuating signal and is transferred to the control surface 3. Hereby there is achieved an adaptation or matching of the deformation of the surface 1 in the sense of a minimization of the induced flow-mechanical resistance of the surface 1, as explained initially above. This is achieved when the measured data representing the actual elastic deformation of the surface 1 correspond with the nominal data representing the desired or nominal deformation prescribed for the aircraft loading and the flight condition.

The principle for a flow-mechanically effective surface of a device moving in a fluid and its elastic deformation for minimizing the induced flow-mechanical resistance, described above in connection with a lifting surface of an aircraft, is similarly transferable or applicable to other types of flying machines, such as to rotary wing aircraft, but also basically applies for other types of flow-mechanically effective surfaces of a device moving in a fluid.